Electroformed Integral Shells for the Con-X HXT: May 2003 Update

CfA

P. Gorenstein
S. Romaine
R. Bruni

OAB

G. Pareschi
O. Citterio
M. Ghigo
F. Mazzoleni
G. Parodi

MSFC

B. Ramsey
C. Speegle
J. Kolodziejczak
S. O'Dell

Presentation Topics

- Review of integral shell mirror and its advantages
- Point out error in TRIP report's description of integral shell mirror
- Reason for coating inner shells with Iridium rather than W/Si
- Installation of Jensen-Christensen collimator in deposition chamber
- Impending stress tests
- Report progress in construction of prototype mirror for X-ray testing

Electroformed Integral Shells for the Con-X HXT

Advantages compared to segmented mirrors

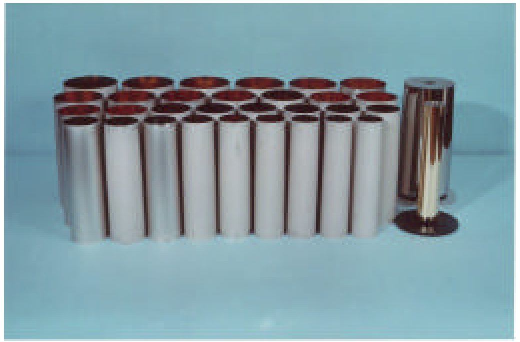
- Expect better angular resolution from stiff closed shells as shown by experience: JET-X/SWIFT 17” HPD, XMM-Newton 15” HPD and recent measurement of thin replica from JET-X (SWIFT) mandrel

- Replication well adapted to making 12 or more identical copies

- Simpler integration of reflectors into a telescope, 90 to 112 shells per telescope, total of 1000 to 1340 shells for all four Con-X S/C

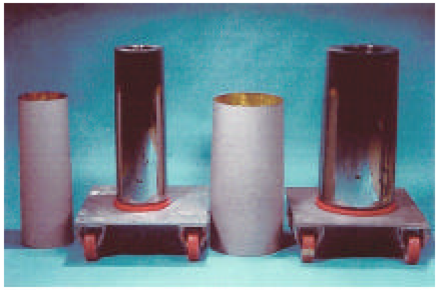
Note: Error in TRIP report, which states there are 5400 shells

Heritage of Electroformed X-ray Telescopes

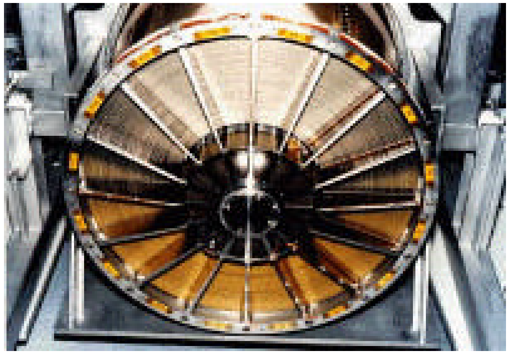


Beppo/SAX

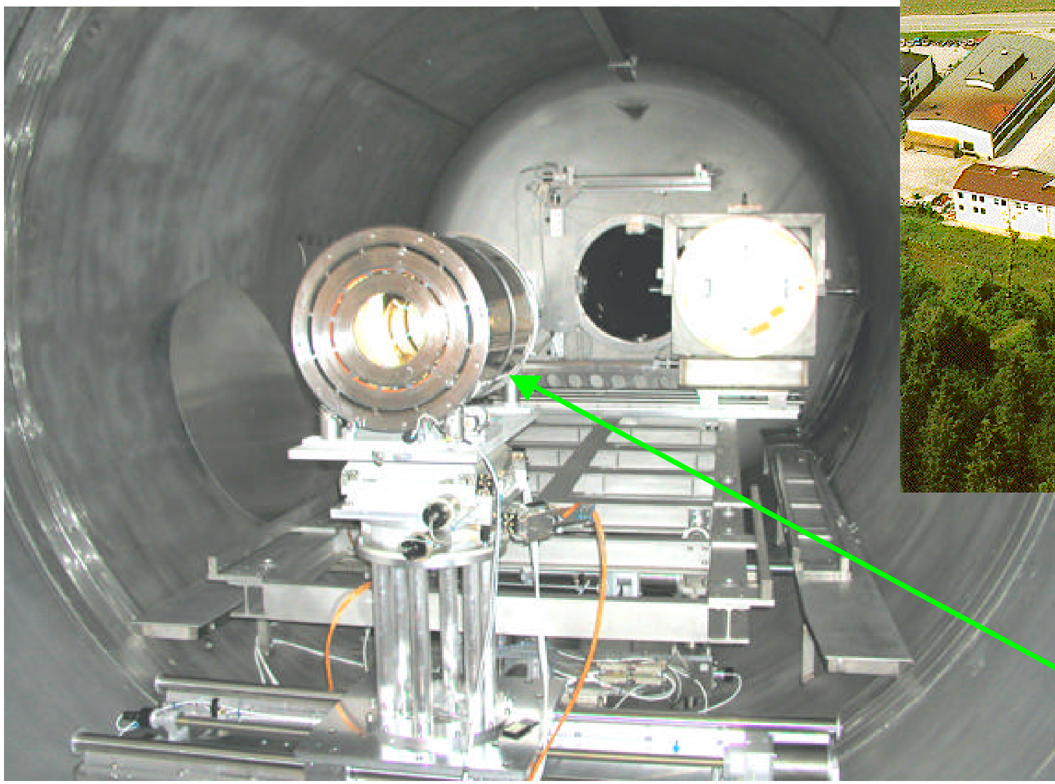
SWIFT/JET-X



XMM-Newton



Full-illumination X-ray tests at the Panter-MPE facility (July '02)

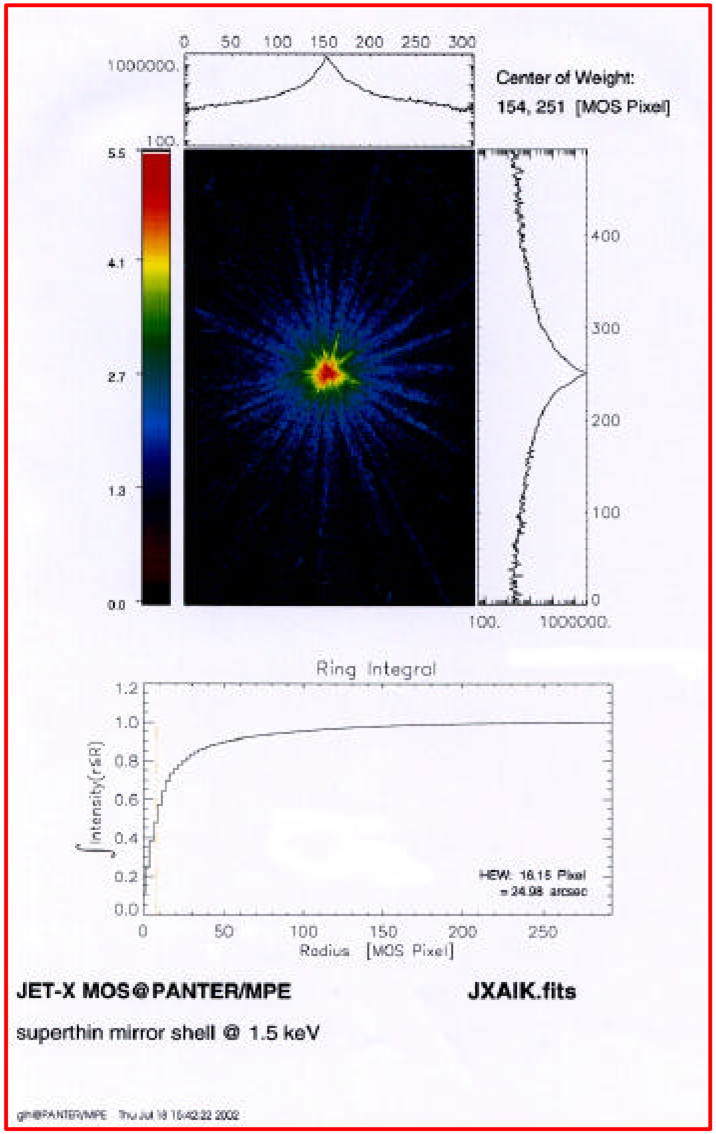


Electroformed Wolter 1 Shell

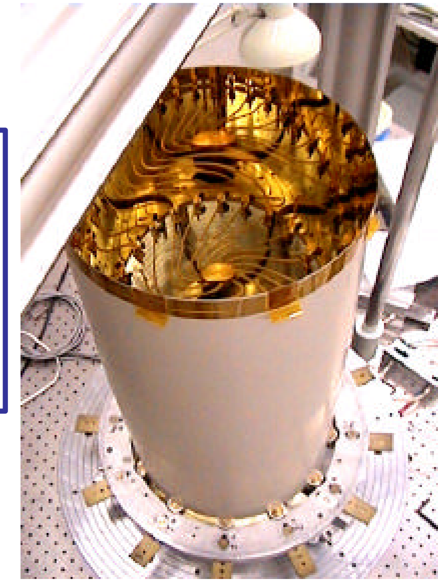
X-ray imaging test of thin shell from JET-X mandrel (July '02)

@ Panter-MPE

1.5 kev, Gold Coating



- Diam. = 30 cm
- **Wall thickness = 130 mic**
- 0.29 XMM shell
- 0.12 SWIFT shell,



HEW_{meas} = 25 arcsec

Mass

Est. mass of electroformed replica telescope for the Con-X HXT is: 53 kg/unit or 159 kg/SC. **This fits within mass allowance.**

Shell/diameter thickness ratio is **0.12 SWIFT/JET-X, 0.29 XMM**

Mean HXT substrate thickness is 110 microns, Ni density is 8.9
Thickness x density = 979

Mean SXT substrate thickness is 440 microns, Glass density is 2.5
Thickness x density = 1100

Electroformed HXT substrates are less dense than SXT's

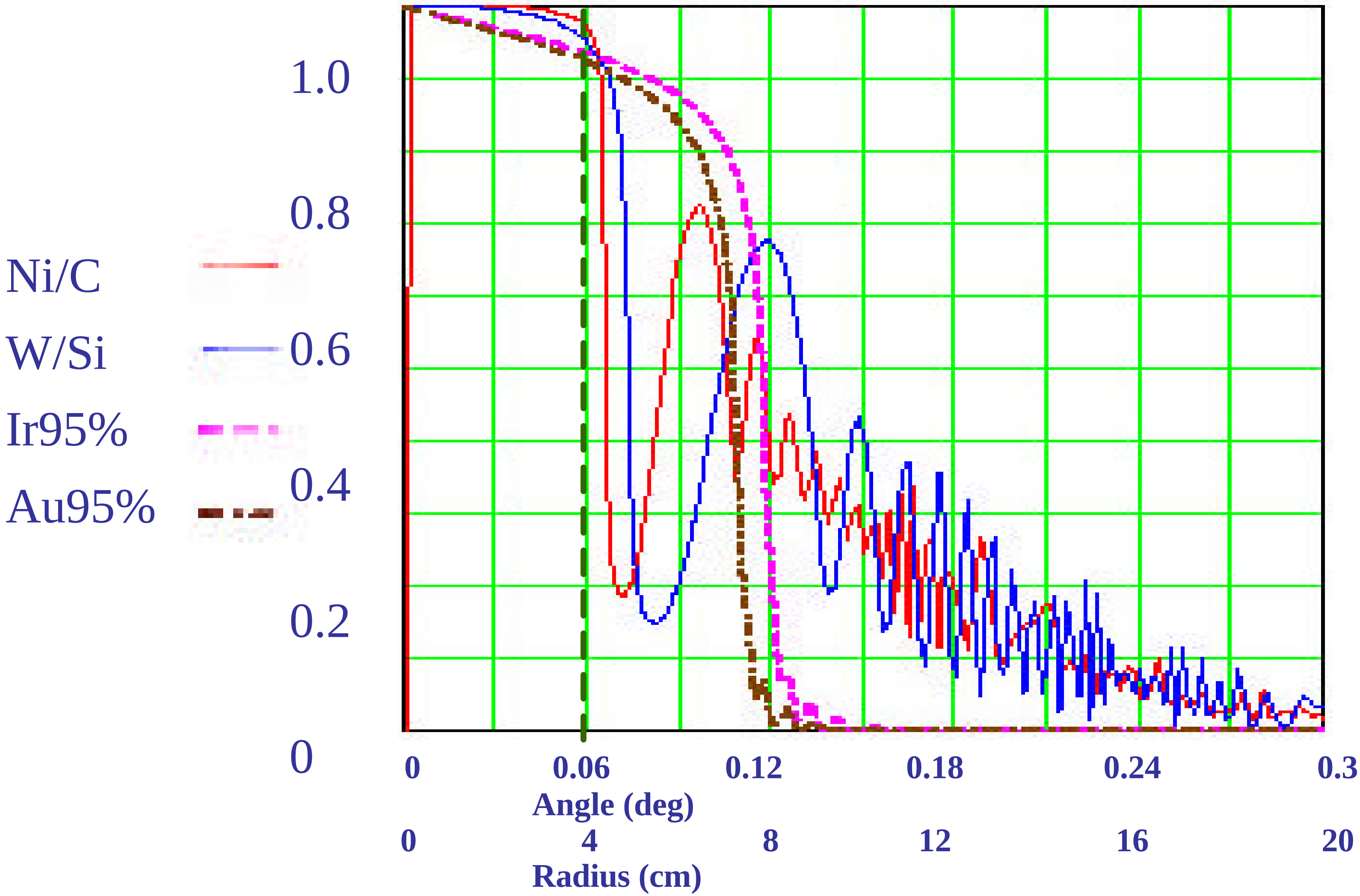
Inner Shells are Coated with Iridium, Outer Shells with W/Si Multilayer

- **Larger effective area at 40 keV**

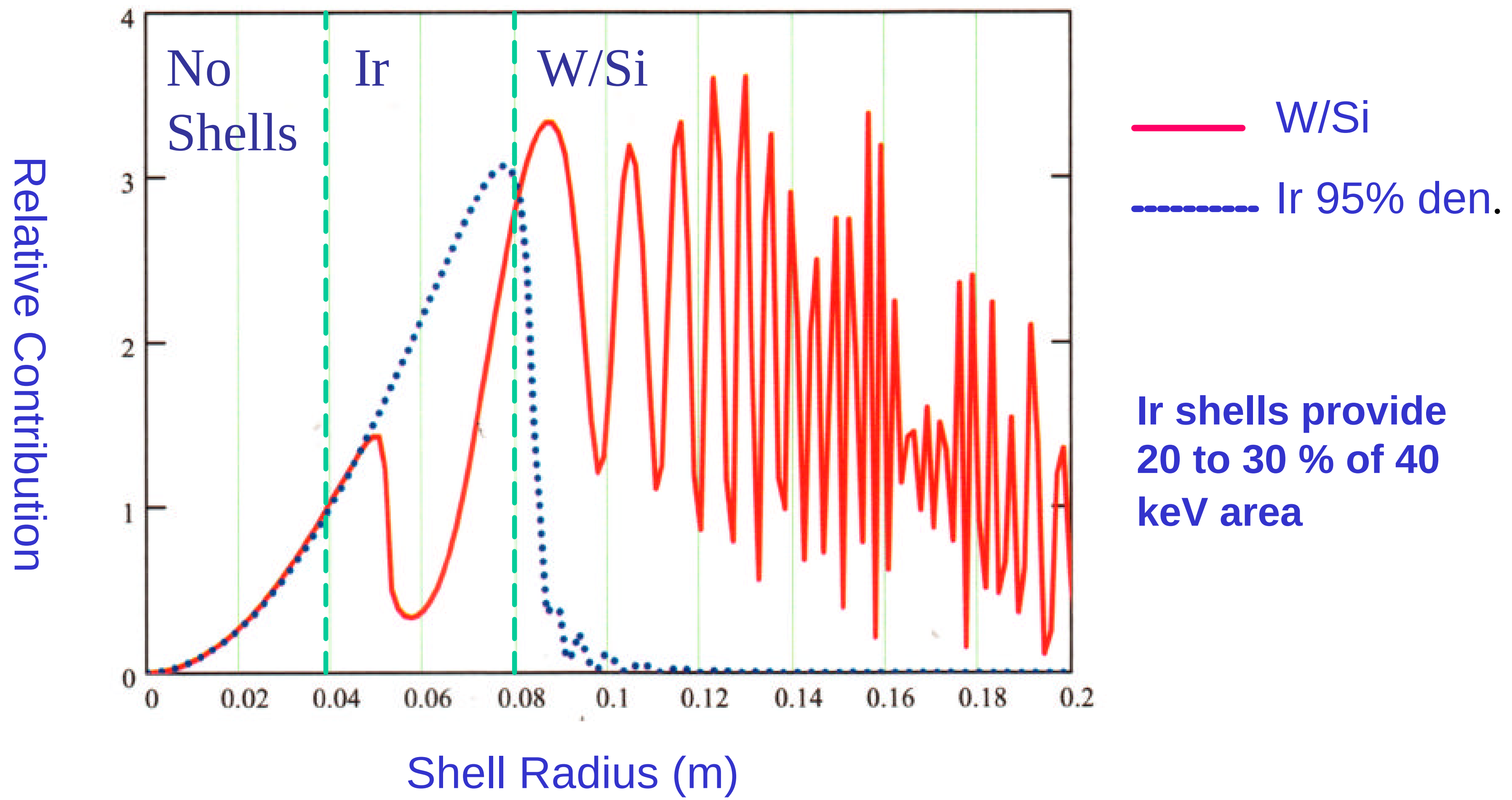
- **Lower cost,**
  mandrels for Ir shells do not have to be polished as thoroughly as the mandrels for the W/Si shells

- **Faster production**
  Depositing single layer Ir requires less time and effort than depositing W/Si ML

40 keV Reflectivity Vs. Angle for Several Coatings

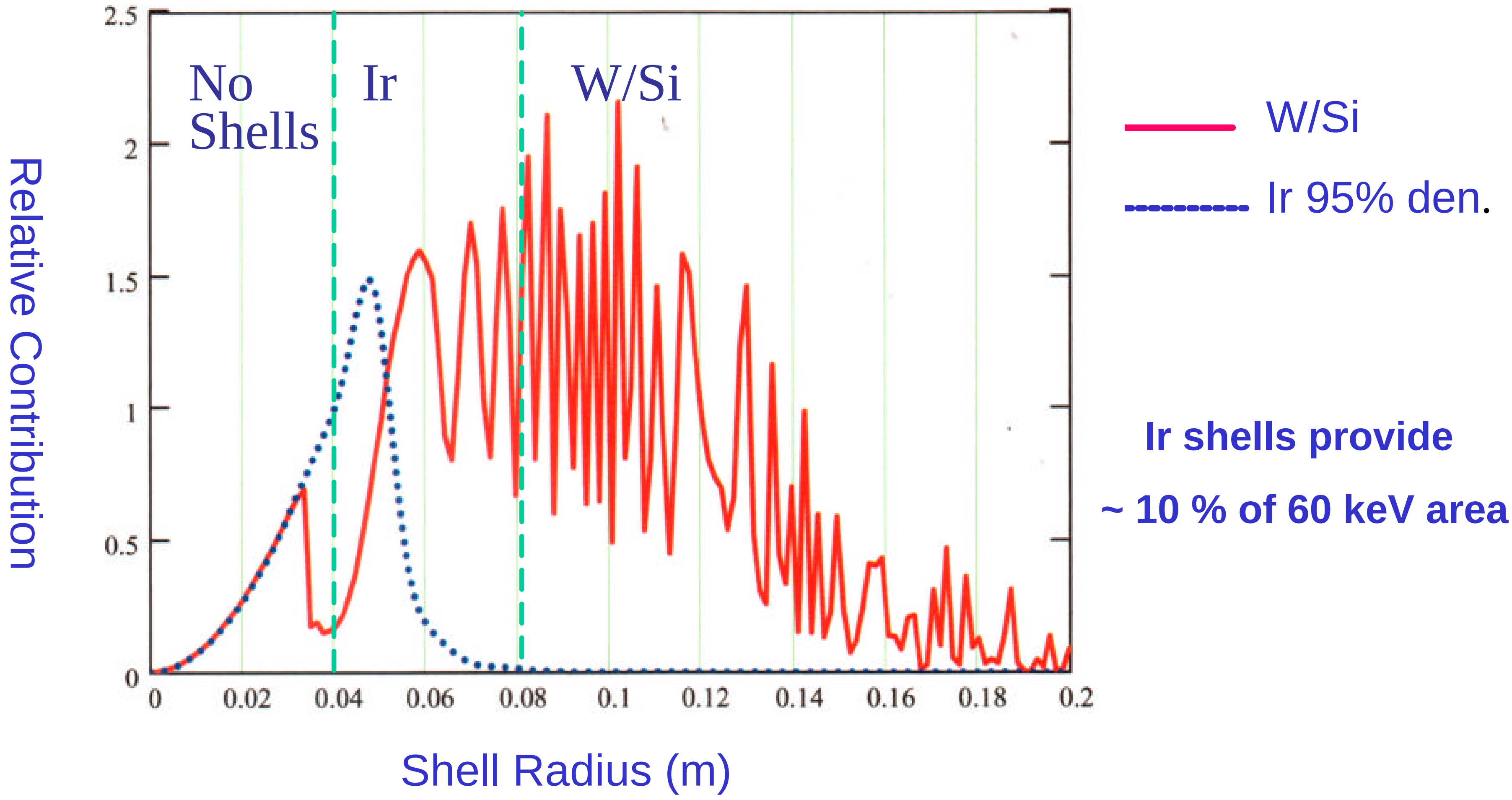


Relative Contribution to 40 keV Effective Area as a Function of Shell Radius
Change coating from Ir to W/Si at 8 cm radius



Ir shells provide 20 to 30 % of 40 keV area

Relative Contribution to 60 keV Effective Area as a Function of Shell Radius
Change coating from Ir to W/Si at 8 cm radius

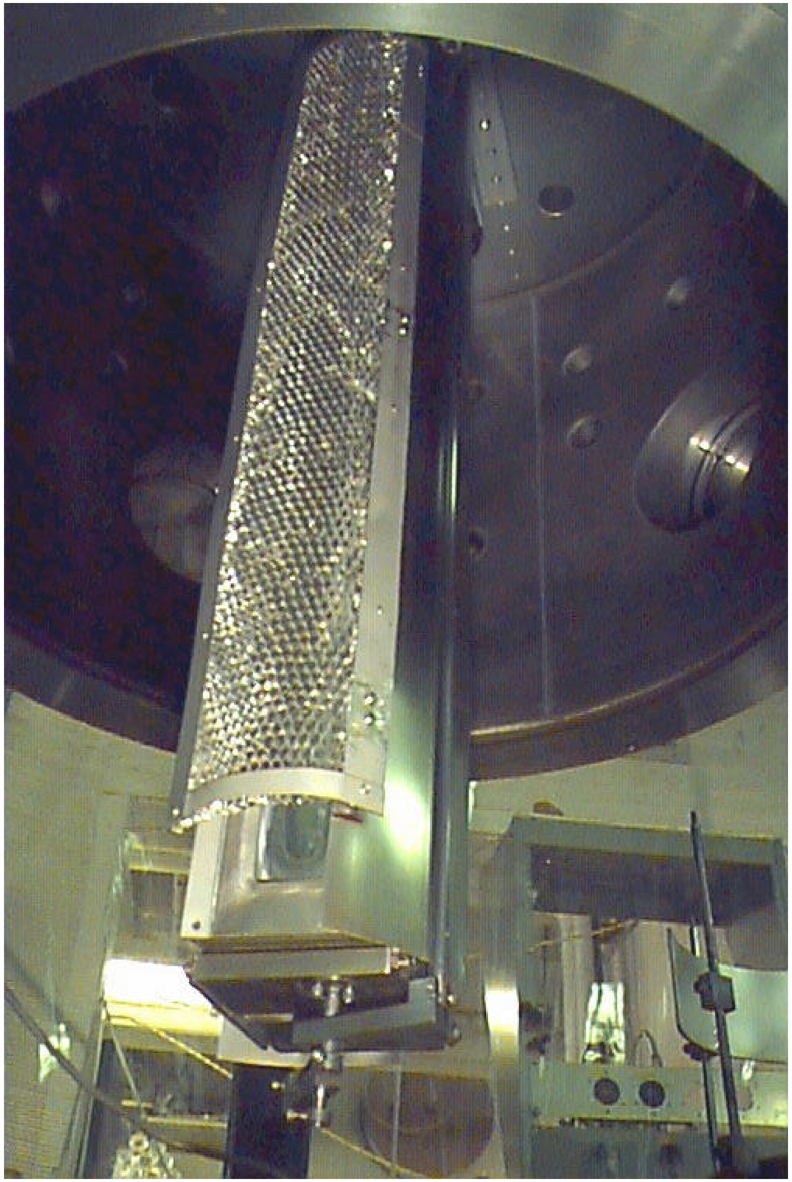


Ir shells provide

~ 10 % of 60 keV area

Result of Coating Inner Shells with Ir and Outer Shells with W/Si
Per Cent Change in Effective Area With Respect to All with W/Si

Shell Range **Outermost - Innermost** 0 - 100 Coating	40 keV	60 keV
1 - 55 W/Si 56 – 112 Ir	+ 30 %	- 26.7 %
1 – 83 W/Si 84 – 112 Ir	+ 11.5 %	0 %

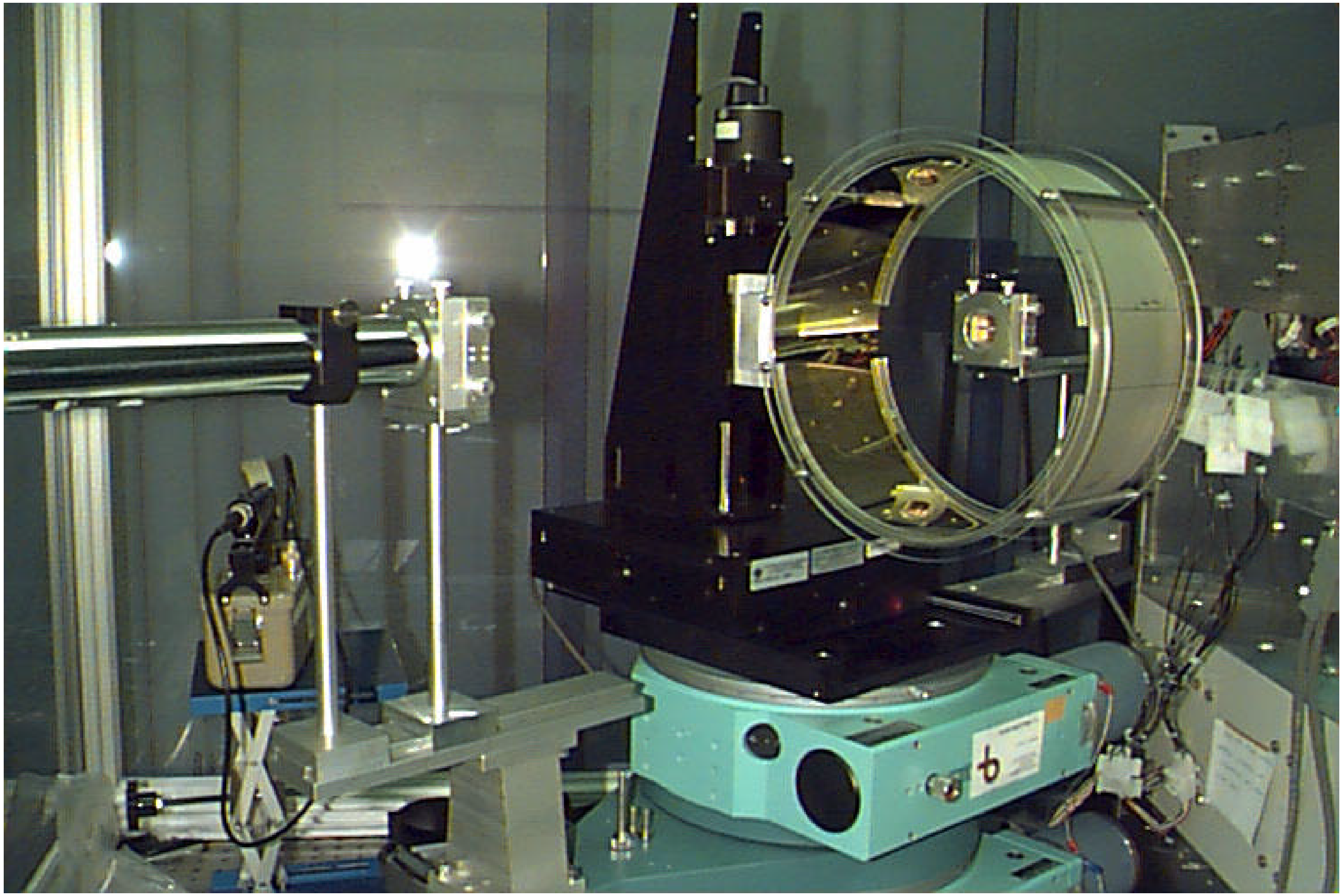


Jensen and Christensen, 2002 reported that the roughness of a multilayer coating can reduced by installing a collimator between the source and the target substrate

Introducing collimator in SAO chamber reduced WSi interface roughness.

4.5 $\longrightarrow$ 3.5 A rms
on Si Wafer

Small Length Shell with W/Si on Only ~ 45 deg. of Azimuth



Stress in Multilayer Coatings

- Coating shell only portion of azimuth (to allow multiple depositions on single shell) resulted in distortion

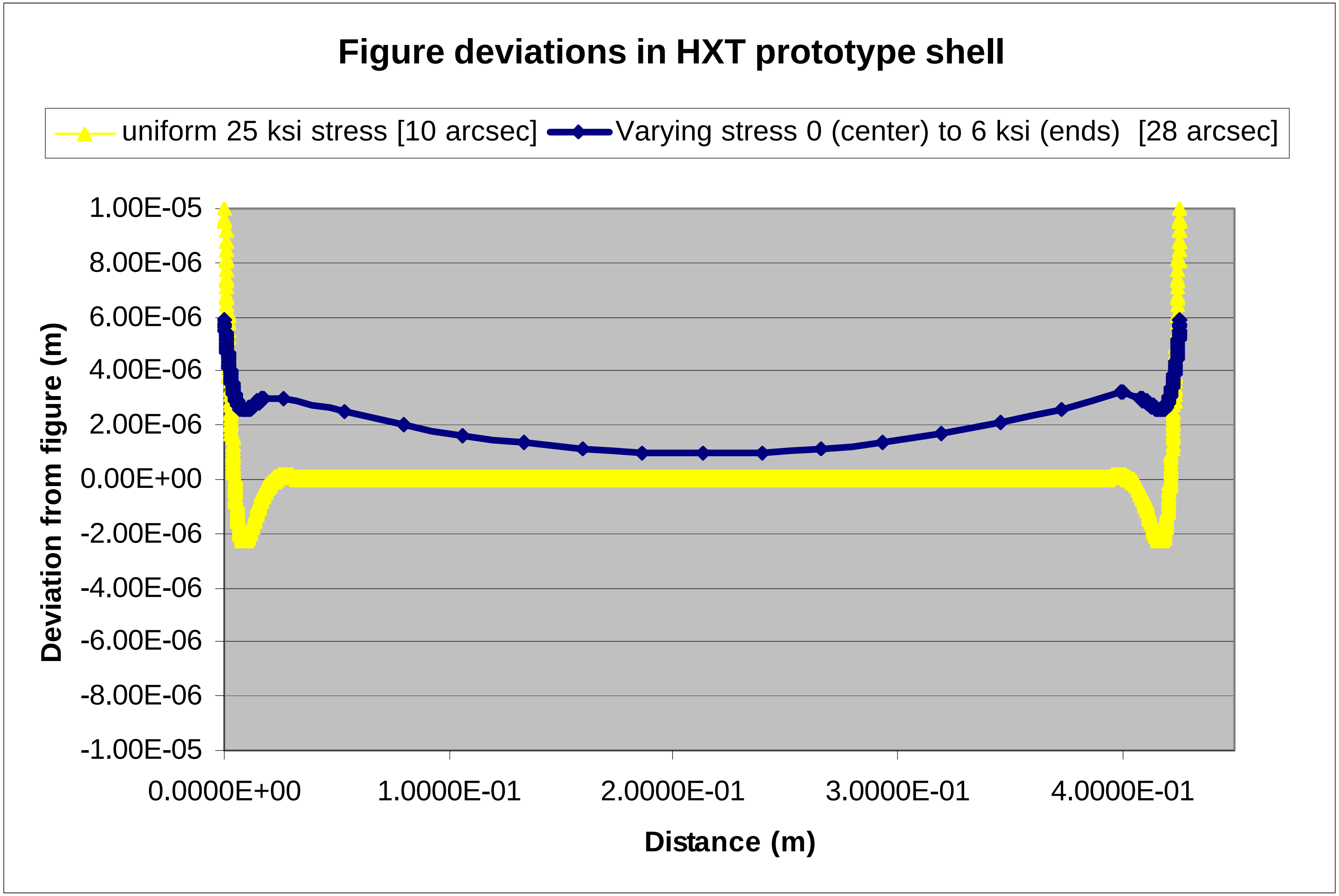
- Measured stress for 30 layers, 4 nm period, W/Si on Si wafer is few 100 Pa

- Stress is partially intrinsic and partially a result of mismatch in coefficients of thermal expansion between Ni shell and W/Si coating

- Not clear if this is a problem for uniformly coated shells with uniform stress; where we expect only end effects

- Modelling by MSFC indicates that if there are no axial temperature gradients during coating the effect upon the resolution is small

MSFC Model of Effect of Stress in Coating Upon Resolution



MSFC Shells for Stress Tests on Fully Coated Shells




- MSFC has fabricated 4 shells (not smooth mandrel)
- Initial measurements of figure, this week (May 5)
- Delivery to SAO for coating. week of May 12
- Return to MSFC for figure check, week of May 26

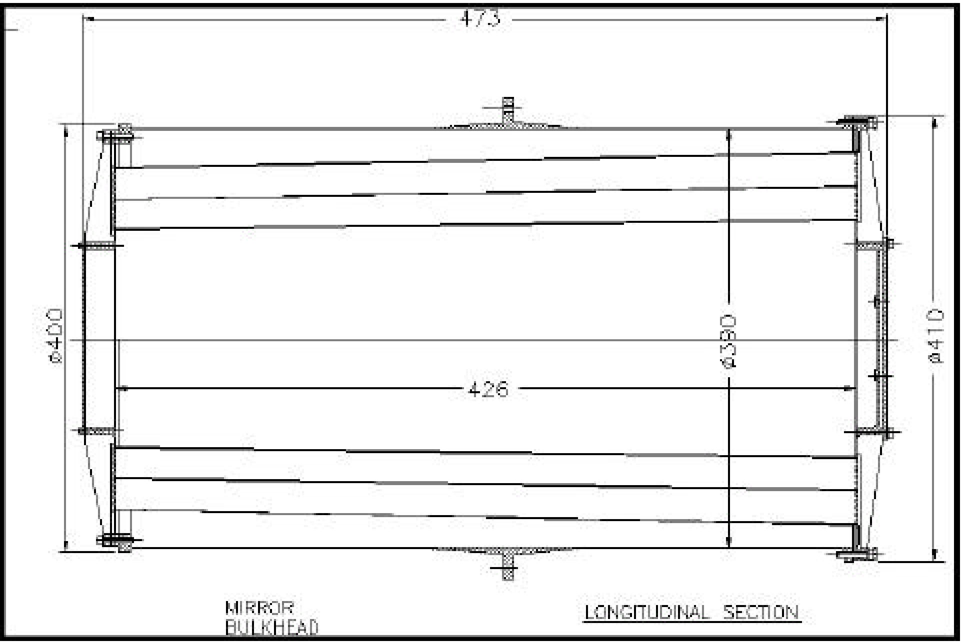
Measures to Relieve Stress

If stress is a problem for uniformly coated shells

- Adjust pressure during coating process
- Anneal shells
- If the above fail: coat the outside of the shells with single layer of W to balance stress from interior layer

SAO/OAB/MSFC Integral Shell Prototype For X-ray Testing

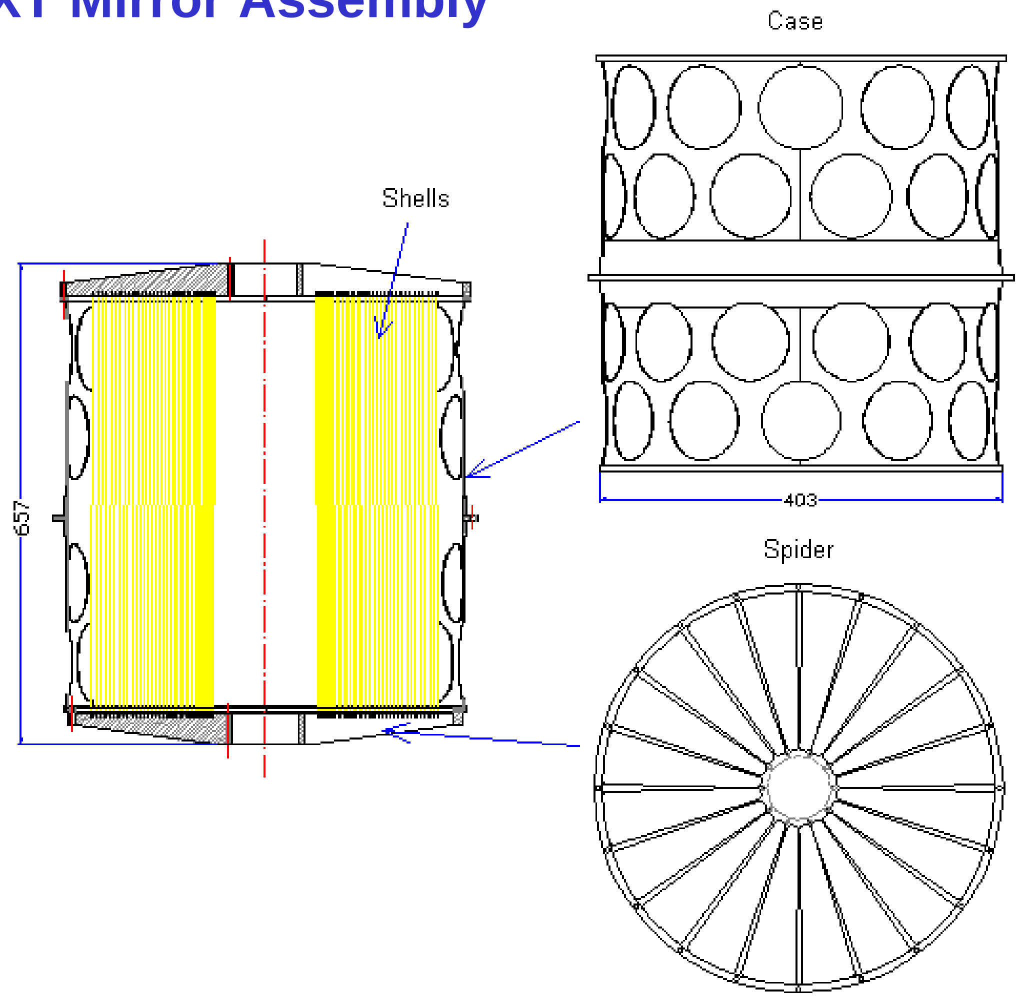
Focal Length = 10000 mm
Mirror length = 426 mm



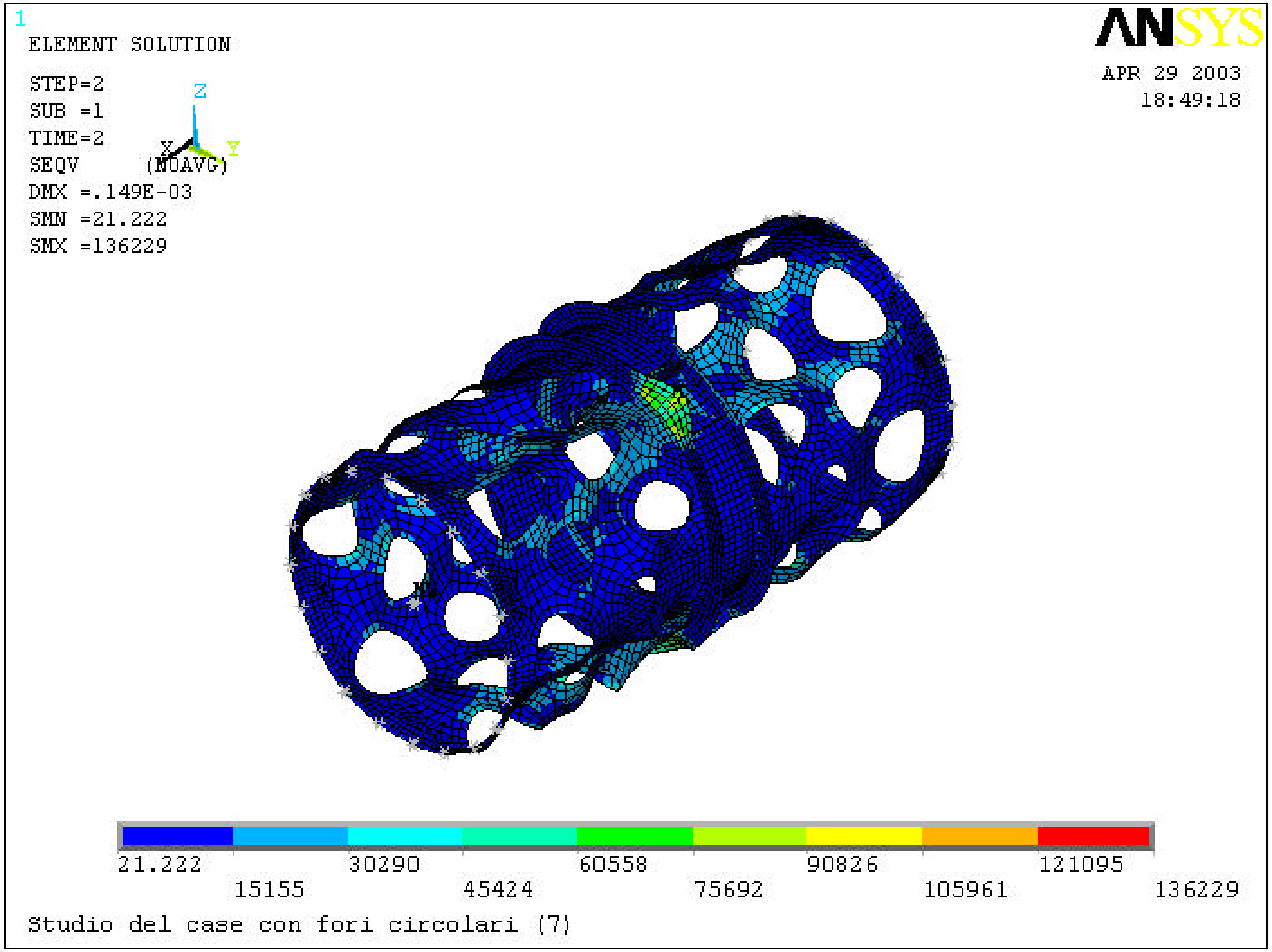
- ✓ **3 shells (Æ = 250, 270, 280 mm) provided by OAB;**
- ✓ **deposition of the multilayer films at CfA;**
- ✓ **2 additional shells (Æ = 240 and 150 mm) provided by MSFC. The 150 mm shell will be coated with single layer, Ir;**
- ✓ **integration at OAB;**
- ✓ **full-illumination tests at the 102 m Hard X-ray facility of NASA/MSFC.**

X-ray tests to be re-schedulated from: Summer 2003

Prototype HXT Mirror Assembly

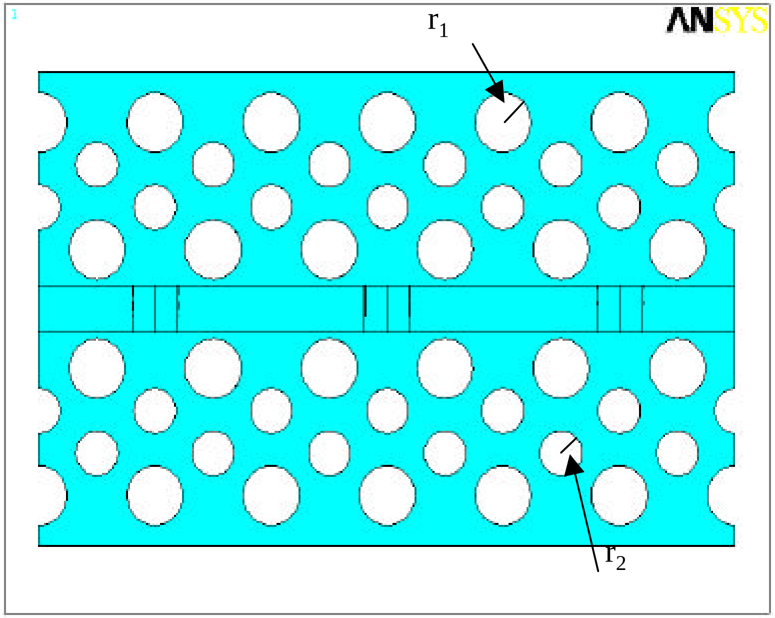


OAB Structural Analysis of Support Case

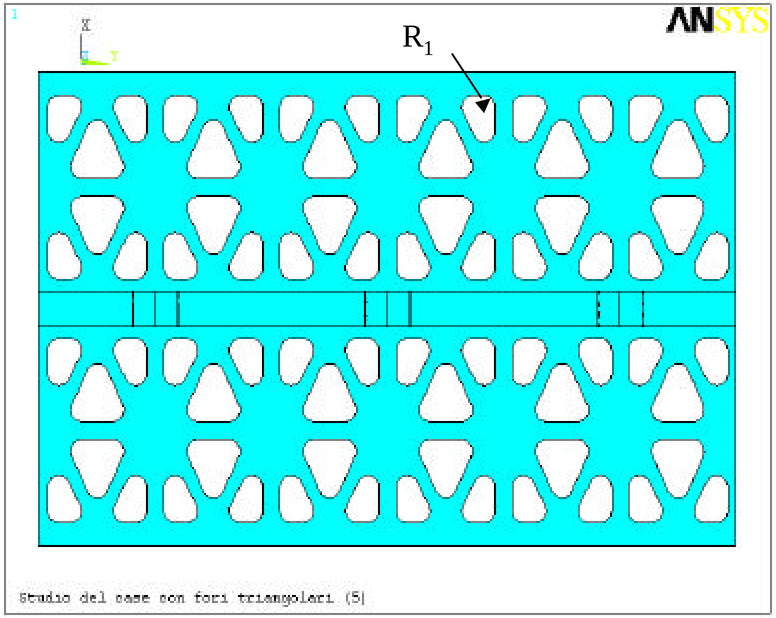


OAB Structural Analysis of Support Case

Round Holes



Triangular Holes



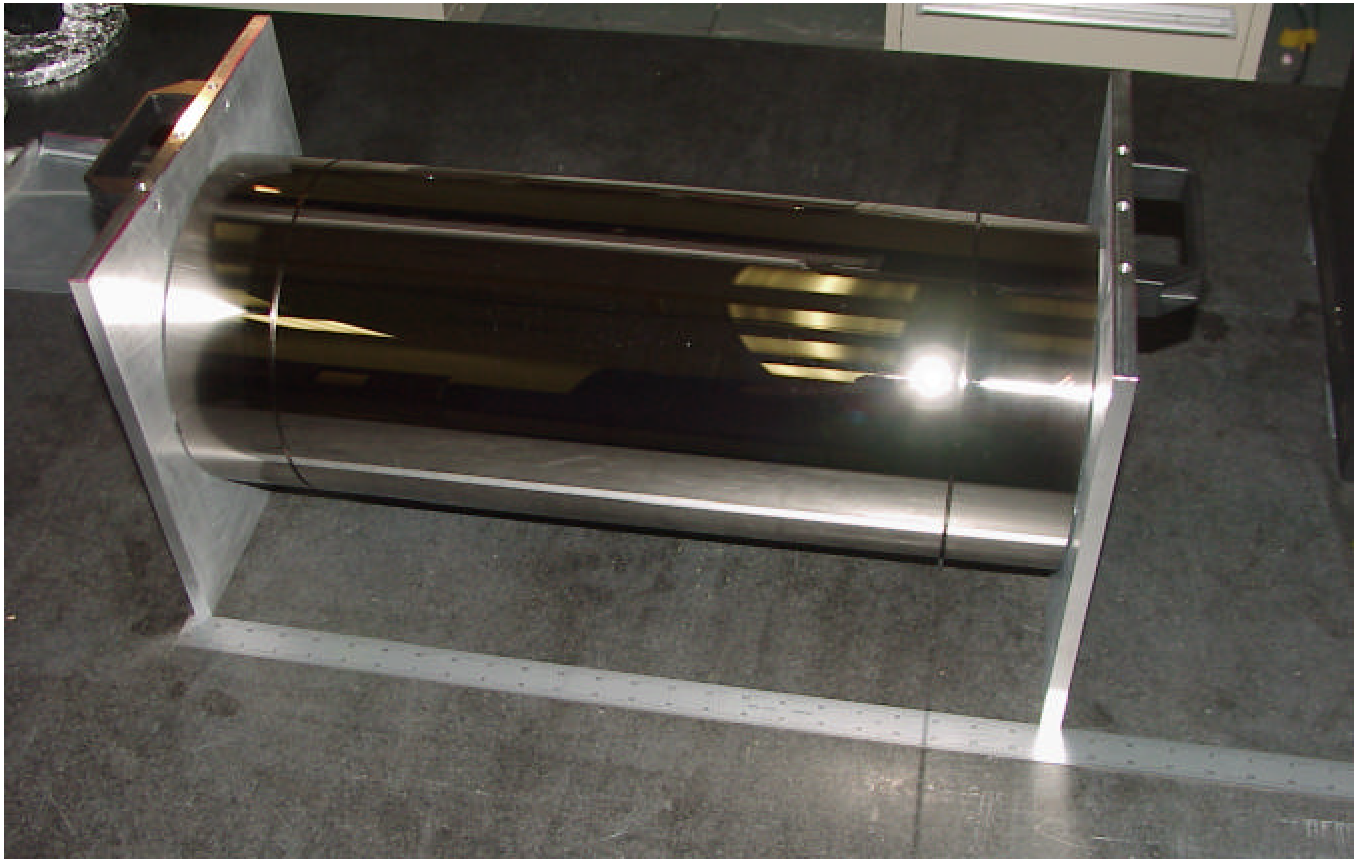
OAB Structural Analysis of Support Case

Name		Circular 6	Circular 7	Triangular 5
Image		Fig. 1	Fig. 1	Fig. 2
Case thickness	[mm]	1.1	1.1	1.2
R1	[cm]	5.0	5.0	2.0
R2	[cm]	3.75	3.75	---
Ribs at the edge of holes		Yes	No	No
Total mass (*)	[kg]	54.3	54.4	54.0
Von Mises equivalent stress (20g +x)	[MPa]	205.5	136	234.4
Von Mises equivalent stress (20g +y)	[MPa]	127.4	302	195.9
Von Mises equivalent stress (20g +z)	[MPa]	134.0	320	209.6
Frequency (I mode)	[Hz]	68.2	70.7	63.9
Euler critical factor (20g +x)		14.6	9.14	5.19
Euler critical factor (20g +z)		7.8	4.31	3.25

(*) case + spiders + mirror shells.

High Resonant Frequency

MSFC Polished Mandrel For Prototype Mirror



3 Mandrels in Different Stages of Preparation at OAB